Not all distractions are the same: Investigating why preschoolers make distraction errors when switching

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Abstract

When switching between tasks, preschoolers frequently make distraction errors – as distinct from perseverative errors. This study examines for the first time why preschoolers make these errors. One hundred and sixty-four two- and three-year-olds completed one of four different conditions on a rule-switching task where children sorted stimuli according to one rule and then switched to a new rule. Conditions varied according to the type of information that children needed to ignore. Children made significantly more distraction errors when the to-be-ignored information was related to the previous rule. When it was not related to a previous rule, even young preschoolers could disregard this information. This demonstrates that distraction errors are caused by children's initial goal-representations that continue to affect performance.

Introduction

Cognitive flexibility (CF) allows us to adjust our behavior in response to changes in our goals. CF develops rapidly during the preschool years, allowing children to engage in adaptive, goal-directed behavior (e.g., Zelazo, Müller, Frye & Marcovitch, 2003). Nevertheless, it is typical for preschoolers to have difficulty in behaving flexibly. For example, 3-year-olds frequently make errors when switching from sorting stimuli by color to sorting them by shape (Deák, 2003; Espy, 1997; Zelazo, 2006). These errors can be split into two distinct types. Children may make errors by consistently continuing to sort stimuli by an old rule (perseverative errors). Alternatively, they may make sporadic errors that are neither compatible with the old rule nor the new rule (distraction errors). Perseverative errors have been the predominant focus of the literature, since many paradigms can only detect perseverative errors (Chevalier & Blaye, 2008; Cragg & Chevalier, 2012). Thus, theoretical accounts of CF development have tended to focus on the apparent shift from perseverative responding to flexible responding (Diamond, Carlson & Beck, 2005; Perner & Lang, 2002; Munakata, Snyder & Chatham, 2012; Zelazo *et al.,* 2003). However, recent research has shown that distraction errors can be just as common as perseverative errors, particularly in younger preschoolers (Blakey, Visser & Carroll, 2016; Chevalier & Blaye, 2008). Therefore, focusing solely on one type of error is to mischaracterise the development of CF. Nevertheless, there is little research examining *why* distraction errors arise. The present paper seeks to address this by systematically examining the cause of preschoolers' distraction errors.

Resisting distraction from information unrelated to the current task is an essential aspect of goal-directed behavior. Distraction errors occur in infants (Diamond, 1985), toddlers (Zelazo, Reznick & Spinazzola, 1998), preschoolers (Blakey *et al*., 2016; Brooks, Hanauer, Padowska & Rosman, 2003; Chevalier & Blaye, 2008; Deák & Wiseheart, 2015) and adolescents (Crone, Ridderinkhof, Worm, Somsen & van der Molen, 2004) – though we still have little understanding of why they occur. Distraction errors arise when children select a response that is not correct according to either the current rule, or the previous rule. These errors are attributed to children temporarily failing to apply the appropriate rule (in contrast to perseverative errors, where children successfully apply a no-longer appropriate rule). These errors have been documented in preschoolers on the Preschool Attention Switching Task-3 (PAST-3: Chevalier & Blaye, 2008), in which children were required to switch from sorting by one rule ("select only *yellow* stimuli") to sorting by another rule ("select only *blue* stimuli"). On each trial, there were three possible response options, such that when the rule changed, preschoolers could make one of three possible responses. They could switch rule successfully, they could perseverate, or they could make a distraction error by selecting a response from a never-relevant dimension (for example, by switching from selecting yellow stimuli to selecting green stimuli). On this task, 3-year-olds were equally likely to make distraction errors as perseverative errors.

Notably, preschoolers' distraction errors are not limited to a single paradigm. Blakey *et al.* (2016) studied CF in 2.5- and 3-year-olds using the Switching, Inhibition and Flexibility task (SwIFT). There were two contrasting conditions: the Conflicting condition and the Distracting condition. Both required children to switch from sorting stimuli by one rule (e.g., color) to sorting by a new rule (e.g., shape). However, they differed crucially in terms of the stimuli in the post-switch phase. In the Conflicting condition, post-switch stimuli could be matched according to the pre-switch rule (that is, it was possible for children to perseverate). In the Distracting condition, post-switch stimuli *could not* be matched according to the pre-switch rule (that is, it was not possible for children to perseverate – so that any errors they made would necessarily be distraction errors). In the Conflicting condition, children could only sort correctly if they managed to resolve response conflict; conversely, in the Distracting condition, children did not have to resolve response conflict to sort correctly; the stimuli they had to sort could not be matched by the old rule, so the principal challenge they had to meet was to ignore irrelevant information. Preschoolers made similar numbers of errors in each condition, showing that when they fail to switch, they reliably make both perseverative errors and distraction errors. Together, these studies demonstrate that following a rule change, it is not the case that preschool children will necessarily *either* switch successfully *or* perseverate with the initial rule. For this reason, to focus only on errors of perseveration is to ignore a significant proportion of children's behavior on switching tasks.

Distraction errors are intriguing because they occur in the absence of response conflict (see Blakey *et al.,* 2016). To state the problem simply: removing response conflict from measures of CF still leaves significant demands, but we know very little about what these demands *are*. To our knowledge, there has been no research examining the cause of children's distraction errors. Prevailing theoretical accounts of CF development offer little to explain how distraction errors arise. Instead, they focus on explaining how children overcome perseveration on tasks involving response conflict (see Cragg & Chevalier, 2012; Munakata, Snyder, & Chatham, 2012). The aim of this paper is to directly address this gap in the literature, in two ways: firstly, and chiefly, by using a switching task to look at distraction errors, and systematically varying the conditions under which children must switch rules. This will allow us to directly test competing hypotheses to explain the source of distraction errors. Secondly, we will use measures of working memory and inhibitory control to examine the contribution of core cognitive processes known to underpin CF. We focus on 2- and 3-year-olds, as it is during this time that the ability to switch behavior in line with explicit rules first emerges (Blakey *et al.*, 2016; Carlson, Mandell & Williams, 2004). Gaining further direct insights into how flexible behavior emerges during this time is essential for developing a more comprehensive understanding of CF.

We set out three hypotheses to explain why distraction errors arise; the present study will test all three directly. Each hypothesis focuses on a specific task demand that may be problematic for young children when they switch rules. Distraction errors may arise (i) because of children's difficulty with ignoring *any* kind of distracting information (the Goal-Unrelated hypothesis); (ii) because of difficulty ignoring information that used to be relevant (the Goal-Related hypothesis); or (iii) because of difficulty re-engaging with information that was previously ignored (the Reactivation Deficit hypothesis – see also Chevalier & Blaye, 2008). Common to all three hypotheses is the idea that children's distraction errors are driven by the information that they must ignore, following a rule change. However, the nature of this to-be-ignored information is crucially different in each case.

The Goal-Unrelated hypothesis suggests that distraction errors arise due to children having a general difficulty in ignoring distracting information; and that when required to focus on a single aspect of a stimulus (such as its shape), they are unable to focus their attention sufficiently. In other words, *any* kind of to-be-ignored information is sufficient to disrupt children's switching behavior, regardless of whether it was associated with a previous goal. This hypothesis posits that errors occur as a consequence of poor selective attention – the process that enables us to focus only on a specific aspect of a stimulus (e.g. its color), while *not* attending to other aspects of the same stimulus (e.g. its shape). Previous research indicates that selective attention is a plausible candidate process to explain how distraction errors arise (Brooks *et al.,* 2003; Hanania & Smith, 2010). For example, Brooks *et al.* (2003) demonstrated that 3-year-olds could successfully switch rules when sorting stimuli on the basis of shape, when those to-be-sorted stimuli were monochrome. However, when irrelevant color information was added to the stimuli, 3-year-olds failed to switch rules. The authors suggested that the irrelevant information made it more difficult for children to attend to the relevant dimension as children fail to tune out these features (see Neill & Westberry, 1987;

Tipper, Bourque, Anderson, & Brehaut, 1989). Furthermore, when the need to selectively attend is removed, such as during reversal-shift tasks (where children attend to the same dimension as before the switch, but make a different response) children's difficulties with switching disappear (Brooks *et al*., 2003; Perner & Lang, 2002; Zelazo *et al*., 2003)..

Alternatively, it may be that distraction errors occur because children continue to preferentially attend to information relevant to a previous goal. In other words, children's post-switch behaviour may be influenced by a persisting attentional bias established during the pre-switch phase. We refer to this view as the Goal-Related hypothesis. The Goal-Related hypothesis proposes that distraction errors arise because cognitive biases set up during the pre-switch phase lead children to preferentially attend to information *relevant to the previous goal*. In other words, children can ignore most kinds of irrelevant information; however, if the information they must ignore relates to a rule they had been previously following, then their behavior is liable to be disrupted. Note that this is distinct from perseveration (which is the continued use of a no-longer relevant rule). The present suggestion is that *even when* children successfully adopt a new rule, their behavior will still be prone to disruption by information relevant to the previous rule. This view differs from the Goal-Unrelated hypothesis, in that it would predict that children can ignore most kinds of distracting information, with the exception of information specifically relevant to the previously relevant rule.

The Reactivation Deficit hypothesis suggests that distraction errors arise due to difficulties in re-engaging attention towards a dimension that has previously been ignored. It is a common feature of many CF tasks that, following a rule change, the previously suppressed dimension now becomes relevant, requiring children to re-engage their attention to something they had previously actively suppressed. If the Reactivation Deficit hypothesis is correct, this suggests that distraction errors arise as a consequence of a process of active suppression – one where non-relevant information in the pre-switch phase is suppressed. Reactivating a previously ignored dimension is a common demand on many switching tasks (e.g., Chevalier & Blaye, 2008; Müller, Dick, Gela, Overton & Zelazo, 2006; Zelazo *et al.,* 2003), and has been shown to increase perseverative errors. In this context, errors due to difficulties reactivating ignored information are known as 'negative priming'. For example, Zelazo *et al*., (2003) and Müller *et al*., (2006) reported that when children had to attend to stimulus values that they had previously ignored during the pre-switch phase of the DCCS, they made significantly more errors when switching than in a condition where this demand was removed. It is plausible, therefore, to suggest that preschoolers' difficulties with reactivating stimuli they have previously ignored may also give rise to their distraction errors. (Note that this possibility is not mutually exclusive with the Goal-Related hypothesis – both processes may have a significant effect on children's switching behavior.)

The present study aimed to test these three hypotheses for explaining distraction errors in 2.5- and 3-year-olds. Performance was compared across four different versions of the SwIFT designed to separate out these different demands. The SwIFT is a matching task administered on a touchscreen computer. It requires children to match stimuli to one of two response options, according to a given rule for eight trials (the pre-switch phase); and then to match the stimuli by a new rule for eight trials (the post-switch phase). As the aim of the present study was to examine distraction errors, and not perseveration errors, there was no response conflict in any condition (i.e., after a switch, children could not continue to match by the previous rule, and therefore could not perseverate). Instead, in both the pre- and the post-switch phases, children had to match stimuli while ignoring irrelevant information. Measures of working memory and inhibitory control were also included, since working memory and inhibitory control accounts have been influential in explaining perseverative errors (see Cepeda & Munakata, 2007; Diamond, Carlson & Beck, 2005; Diamond &

Kirkham 2005; Munakata, 2001). Therefore this individual difference approach may offer further insights into the contributions of executive functions to distraction errors.

Children completed one of four conditions: the Goal-Unrelated condition, the Goal-Related condition, the Goal-Related Reactivation condition, and the non-switching Baseline condition. The key difference between conditions was the type of information that children had to ignore during the post-switch phase (see Figure 1). To ensure that basic task difficulty across conditions was equivalent, in all four conditions, children sorted *exactly* the same stimuli by *exactly* the same rule during the final eight trials that constitute the post-switch phase. Any between-condition differences cannot therefore be attributed to incidental differences in the post-switch sorting rule or stimuli, since there are none. The only difference between conditions is in the type of information that children attend to initially during the pre-switch phase, and which they must then ignore while sorting during the last eight trials of the post-switch phase. Therefore, it is this pre-switch phase that determines whether the information children must ignore in the post-switch phase was relevant to the pre-switch rule, or involved reactivating a previously ignored dimension.

In the Goal-Unrelated condition, children had to ignore task-irrelevant information unrelated to the pre-switch rule. If the Goal-Unrelated hypothesis is correct, and distraction errors are caused by difficulties in selectively attending to a new dimension in the presence of any task-irrelevant information, then children should find this condition difficult, and as difficult as the Goal-Related condition. In the Goal-Related condition, children had to ignore task-irrelevant information that was related to the dimension they sorted by during the pre-switch phase. If the Goal Related hypothesis is correct, and distraction errors are caused by persisting preferential attention towards information related to a previously relevant rule, then children should find the Goal-Related condition difficult – and *more* difficult than the Goal-Unrelated condition. The Goal-Related Reactivation condition was similar to the Goal

Related condition, but with the added demand of sorting by a dimension that was previously ignored during the pre-switch phase. If the Reactivation Deficit hypothesis is correct, and active suppression of irrelevant information in the pre-switch phase causes additional difficulties that lead to distraction errors, children should find this condition *more* difficult than the Goal-Related condition. We also included a non-switching Baseline condition in which children sorted by the same rule across all trials, without switching rules at any point. This condition offers an index of how well children sort these stimuli in the absence of any need to switch.

Method

Participants and Design

One hundred and sixty-four 2.5- and 3-year-olds took part in the study (87 males and 77 females). Data from a further three children were excluded: two children were later diagnosed with specific language impairment, and one child did not understand the task instructions. The remaining sample was split into two age groups spanning six-month bands: 89 2.5-year-olds (*M* age: 2;9 years; range: 2;6 years – 2;11 years) and 75 3-year-olds (*M* age: 3;3 years; range: 3;0 years – 3;6 years). Children were randomly allocated to one of four conditions: Baseline (21 2.5-year-olds and 19 3-year-olds), Goal-Unrelated (23 2.5-year-olds and 18 3-year-olds), Goal-Related (21 2.5-year-olds and 20 3-year-olds), or Goal-Related Reactivation (24 2.5-year-olds and 18 3-year-olds). Children were recruited either from a database of local families who had expressed an interest in participating in research, or from local preschools. All children were monolingual, predominantly white British and were from working-class and middle-class areas of the UK. Informed consent was obtained from parents before testing began. Ethical approval was obtained from the department's ethics sub-committee. Participating families received a small gift as a token of appreciation for taking part.

Procedure

Children were tested in a single session, either in the University Developmental Lab with their caregiver present, or in a quiet area of their nursery. Children completed three tasks in a fixed order: the SwIFT, the Fruit Stroop (a measure of inhibitory control), and Spin the Pots (a measure of working memory).

The SwIFT: Children completed one of four conditions . The SwIFT is a rule-switching task presented on a touchscreen computer (see Blakey *et al.*, 2016). Children had to decide which of two colorful shapes matched a prompt image on the relevant dimension for that trial (either color, pattern or shape). Task stimuli are made up of different combinations of nine different colors, nine different shapes and nine different patterns. This use of a large diverse stimulus set is desirable when studying early CF, as it reduces the likelihood of stimulus-related errors, which can arise when children repeatedly sort a small set of stimuli (see FitzGibbon, Cragg & Carroll, 2014). The task was presented on an Iiyama ProLite touchscreen connected to a standard PC running E-Prime software (PST, Pittsburgh, PA). The task began with 4 practice trials, followed by a pre-switch phase of 8 trials using one matching rule, and then a post-switch phase of 8 trials using a different rule. All four conditions used the same stimuli and sorting rule for the eight trials of the post-switch phase. On this task, all response conflict is removed: following the change of rule, children cannot continue to match stimuli by the previously relevant rule.

Each trial began with a prompt stimulus appearing at the top of the screen. After a delay of 1000ms, two response stimuli appeared in the lower corners of the screen. One stimulus was the target (the correct response, as it matched the prompt on the currently relevant dimension), and the other was a distractor (the incorrect response). The target and distractor were equally likely to appear on the left or right. Children were prompted to respond by the recorded instruction "Touch the one that's the same [color / pattern / shape]". Children responded by touching their chosen image. When children selected the correct response, a musical cartoon animation appeared in place of the stimulus selected. When children selected the incorrect response, the display disappeared, no animation was played, and the next trial began. If the child did not make a response, the experimenter repeated the prompt. Rule order was fully counterbalanced. There were four different conditions, differing only in terms of the pre-switch phase (the first 8 trials). The post-switch phase (or the final 8 trials) was identical in all conditions: children sorted by color and ignored shape (see Figure 1).

Baseline condition: In this non-switching condition, children sorted by color and ignored shape throughout the task. In other words, the so-called "pre-switch" and "post-switch" phases were identical, as there was no change of rule.

Goal-Unrelated condition: In the pre-switch phase, children sorted by pattern and ignored color; in the post-switch phase children sorted by color and ignored shape. Therefore, the to-be-ignored information in the post-switch phase (shape) had never been relevant: it was not related to the pre-switch rule.

Goal-Related condition: In the pre-switch phase, children sorted by shape and ignored pattern; in the post-switch phase children sorted by color and ignored shape. Therefore, the to-be-ignored information in the post-switch phase (shape) was the information attended to in the pre-switch phase – and was thus related to the pre-switch rule.

Goal-Related Reactivation condition: In the pre-switch phase, children sorted by shape and ignored color; in the post-switch phase children sorted by color and ignored shape.

Therefore, the to-be-ignored information in the post-switch phase was the information attended to in the pre-switch phase – *and* children had to sort by a dimension in the post-switch phase that had previously been ignored in the pre-switch phase.

The Fruit Stroop task: The Fruit Stroop was used to measure inhibitory control (Kochanska, Murray & Harlan, 2000). In this task, children must inhibit pointing to a more salient, larger stimulus in order to respond to a less salient, smaller stimulus. Children were first shown three big pictures and three small pictures of the same fruits (banana, apple and orange). The experimenter named each big fruit and little fruit in turn. The small fruit pictures were then removed, and children were asked to point to each of the three big fruit pictures. This was to check that children knew the names of each fruit (all children did this successfully). For test trials, children were presented with three pictures, each depicting a small fruit embedded in a different large fruit (e.g. a small banana embedded in a large apple). Children were then asked to point to each of the little fruits ("show me the *little* banana"). Children received a score of 0 if they pointed to the large fruit, a score of 1 if they pointed to the large fruit but self-corrected, and a score of 2 if they pointed to the little fruit. The dependent variable was the summed score from the three experimental trials.

The Spin the Pots task: The Spin the Pots task was used to measure working memory (Hughes & Ensor, 2007). In this task, children had to look for stickers hidden in different locations, and remember where they had searched on previous trials. Eight visually distinct pots with lids were arranged on a rotating tray. Children watched the experimenter put colorful stickers in six of the pots, and the two empty pots were pointed out to the child before testing began. Each search trial began with the experimenter covering the tray with a cloth and then rotating the tray for a few seconds. If the children found a sticker in the pot they selected, they kept it. After each search attempt, the tray was again covered and rotated, and a new search trial began. The task ended either once children had found all six stickers, or after 16 trials had elapsed. The dependent variable was scored as 16 minus the number of trials taken.

Results

Preliminary Analyses. Exploratory data analyses were conducted to check for outliers and to test for normality. Inspection of stem-and-leaf-plots indicated that there were no outliers in the data. However, data for all tasks were significantly negatively skewed, as indicated by significant Kolmogorov-Smirnov and Shapiro-Wilk tests (*ps* $< .001$). Therefore, raw scores were transformed using a logarithmic base 10 transformation (log10) to better approximate normality, and the transformed data were used in all subsequent analyses. (For ease of interpretation, raw scores are reported in descriptive data.)

Preliminary analyses were run to check for age differences between conditions, and to check for any effect of sex on the tasks. A one-way ANOVA showed that age did not vary by condition for the 2.5-year-olds or the 3-year-olds (*p*s $> .54$). There was no effect of sex on Fruit Stroop or Spin the Pots performance (*ps* $> .05$). There was a small but significant effect of sex on SwIFT performance ($t(162) = -2.16$, $p = .034$, $d = 0.30$) with females ($M = 6.52$, $SD = 1.64$) more accurate than males overall ($M = 5.93$, $SD = 1.86$). However, when accounting for condition, this effect disappeared ($p > .05$). Therefore, data were collapsed across sex for subsequent analyses.

One-sample t-tests conducted separately for each age group found that both age groups sorted at above-chance levels in all conditions during the pre-switch phase of the SwIFT (*p*s $< .001$), and were able to perform the basic task well. To test whether pre-switch performance differed across conditions, a two-way ANOVA with age group and condition was run on pre-switch accuracy scores. There was a small, marginal effect of condition on pre-switch accuracy, F (3,156) = 2.61, p = .053, $\eta^2_{partial}$ = .05. Bonferroni *post-hoc* tests showed that there was a non-significant trend for pre-switch accuracy to be lower in the Goal-Related condition, where children sorted by shape and ignored pattern information (M = 6.89, SD = 1.82), compared to the Goal-Related Reactivation condition, where children sorted by shape and ignored colour information (M = 7.50, SD = 1.61), (p = .07). No other comparisons were significant (all *ps* > .1). Pre-switch performance was controlled for in subsequent analyses.

To test whether working memory and inhibitory control performance improved with age, independent-samples t-tests compared working memory and inhibitory control scores by age group. Two 2.5-year-olds and one 3-year-old did not complete the Spin the Pots task, so analyses were run on the remaining 161 children; five 2.5-year-olds and two 3-year-olds did not complete the Fruit Stroop task, so analyses were run on the remaining 157 children. Levene's test for equality of variance was significant for both the Spin the Pots task (F = 9.72, p = .002) and the Fruit Stroop task (F = 5.15, p = .03), so we report the corrected test which does not assume equal variance between groups. There was a significant improvement in working memory between 2.5 years (M = 7.45, SD = 2.58) and 3 years (M = 8.53, SD = 1.80), t (125) = - 3.05, p = .003, d = .49. There was a marginal improvement in inhibitory control between the ages of 2.5 years (M = 4.37, SD = 2.02) and 3 years (M = 4.92, SD = 1.67), t (154) = - 1.82, p = .07, d = .30. Finally, working memory scores and inhibitory control scores were not significantly correlated in 2.5-year-olds, r(82) = .11 , p > .1, nor in 3-year-olds, r (72) = .08, p > .1.

The effect of age and condition on switching performance. To test whether there was an effect of condition on post-switch accuracy, a 4 x 2 ANOVA was run with condition and age group as factors, while controlling for pre-switch performance, which was a significant covariate (F (1,155) = 17.46, p < .001, $\eta^2_{partial}$ = .10. There was a significant main effect of condition on post-switch accuracy (F (3,155) = 6. 94, p <.001, $\eta^2_{partial}$ = .12) (see Figure 2). Bonferroni *post-hoc* tests showed that this was specific to the Goal-Unrelated and Goal-Related conditions. Children in both conditions needed to switch rule while ignoring irrelevant information. However, when the to-be-ignored information was related to the pre-switch rule (as in the Goal-Related condition), children made significantly more errors than when the to-be-ignored information was not related to the pre-switch rule (as in the Goal-Unrelated condition) (p = .02). There was no significant difference between the Goal-Related Reactivation condition compared to the Goal-Related condition (p = 1.0), indicating that there was no additional cost due to having to reactivate a previously ignored dimension. In addition, there was no significant difference between the non-switching Baseline condition and the Goal-Unrelated condition: when children had to switch rules in the presence of task-irrelevant information not related to the previously relevant rule, their performance was no different to not having to switch rules at all (p = 1.0). There was a significant main effect of age on post-switch accuracy, with 3-year-olds (M = 6.76, SD = 1.61) significantly more accurate than 2.5-year-olds overall (M = 5.74, SD = 1.79), (F (1,155) = 4.78, p = .03, $\eta^2_{partial}$ = .03). Finally, the effect of condition did not differ as a function of age: there was no significant interaction between age and condition (F (3,155) = 0.25, p = .86).

To test whether distraction errors were unsystematic and equally distributed across the post-switch phase – or whether children make more errors at the beginning or end of the post-switch phase (for example, due to poor awareness that the rule has changed, or to task fatigue) – paired-sample t-tests were run for each age group and for each condition, comparing accuracy on each half of the post-switch phase (the first 4 trials vs. the last 4 trials). There was no difference between first-half performance and second-half performance on the post-switch phase, for all age groups and all conditions (all ps > .3). This is consistent with errors being unsystematically distributed throughout the post-switch phase.

Individual difference analyses. To investigate how individual differences in inhibitory control and working memory related to switching while ignoring different types of irrelevant information, Pearson's correlations were run for each age group. Because the Goal-Related and Goal-Related Reactivation conditions were not significantly different to one another, their data were combined to increase power. Similarly, because the Baseline condition and the Goal-Unrelated condition were not significantly different, data from these two conditions were also combined. Seven children did not complete the inhibitory control task and three children did not complete the working memory task, so analyses were run on the remaining children. For 2.5-year-olds, neither inhibitory control nor working memory were related to switching accuracy in any condition (all $ps > .05$). For 3-year-olds, inhibitory control was significantly related to switching accuracy, but *only* in the conditions where the to-be-ignored information was previously relevant – the two Goal-Related switching conditions ($r(38) = .31$, $p = .05$). Inhibitory control was not related to switching accuracy when the to-be-ignored information was not previously relevant, as in the Baseline and Goal-Unrelated conditions ($r(35)= .14$, $p = 0.66$). Three-year-olds' working memory was not associated with switching in any of the conditions (all $ps > .05$).

Discussion

The present study aimed to determine what causes distraction errors in preschool children's switching. It was found that children were able to switch rules when they had to ignore distracting information – provided that the information was unrelated to the rule they had previously sorted by. Indeed, performance in this condition was indistinguishable from a baseline condition in which children did not switch rules at all. This supports the view that ignoring distracting information in general is straightforward, even for young preschoolers.

However, children made significantly more distraction errors when the information they had to ignore was related to a previous sorting rule. Notably, their performance was no worse when the requirement to reactivate a previously ignored dimension was also present. These results show that distraction errors do not arise due to general difficulties with selective attention, and that most kinds of non-relevant information can be ignored with relative ease, even by young preschoolers. Instead, distraction errors arise because of continued influence from children's previous sorting behavior, in that information associated with a previously relevant rule disrupts sorting after a change of rule. What is striking is that this influence persists even when children are able to successfully update the rule they sort by. Even the youngest children in the Goal-Related condition sorted successfully on more than half of post-switch trials, demonstrating that they were well able to switch to the appropriate post-switch rule. Nevertheless, their behavior was still disrupted by continued preferential attention to information related to the previous (and now abandoned) rule. Taken as a whole, the present results suggest that children's distraction errors are specifically goal-related in nature, and arise from cognitive biases set up during the pre-switch phase that lead children to attend to information consistent with a rule they previously used.

The next question is to consider what we can say about how executive functions underpin this account. Switching performance in 3-year-olds was significantly predicted by their inhibitory control. However, this was only the case in conditions where the to-be-ignored information was related to a previously relevant rule. This suggests that for 3-year-olds, immature inhibitory control may lead to them being more susceptible to influence from a no-longer-relevant goal. These findings are consistent with previous work showing that preschoolers' inhibitory control is related to their ability to switch in the presence of task-irrelevant information – but that individual differences in working memory are not (Blakey *et al.,* 2016). The present findings go further, suggesting that inhibitory control is *only* required when the to-be-ignored information is salient due to its relation to a previously relevant task. Switching performance in both 2.5- and 3-year-olds was unrelated to their working memory. This indicates that having a good working memory does not shield children from information that is distracting due to its association with a previous task. Working memory may only be important in situations where children must resolve response conflict, since under such circumstances there are strong demands on children to maintain the currently relevant rule (Blakey *et al.,* 2016; Munakata, 2001). This is consistent with research in adults showing that working memory is particularly crucial when response conflict demands are high (Meier & Kane, 2015).

No relation was found between switching and inhibitory control in 2.5-year-olds. This is somewhat surprising, since it contrasts with previous research reporting a positive relation between inhibitory control and switching in the presence of distractions in 2.5-year-olds (Blakey *et al.,* 2016). The reasons for this discrepancy between present results and previous results are unclear. It may be due to unidentified between-sample differences, or it may arise from differences in the way that inhibitory control was measured across the two studies (with the Fruit Stroop task in the present study, and with the Reverse Categorisation task in Blakey *et al.*'s 2016 study). Given that there are strong theoretical grounds to think that inhibitory control helps preschoolers to resist distractions when switching, and given the consistent finding that 3-year-olds' inhibitory control supports their switching behavior, we would speculate that inhibitory control is likely to play a role in 2.5-year-olds' switching. The lack of a positive finding in the present study may indicate that the Reverse Categorisation task is a more sensitive measure of inhibitory control in 2.5-year-olds than the Fruit Stroop task.

In order to further elucidate the specific role of core executive functions in switching, it will be important in future research to include multiple measures of working memory and inhibitory control when examining how these abilities contribute to cognitive flexibility. For example, we may expect there to be a stronger relation between inhibitory control tasks that measure attentional inhibition or conflict inhibition, compared to tasks that measure response inhibition or delay inhibition. Furthermore, including additional measures of each construct would allow researchers to compute composite scores, which minimise task specific variance. The ease with which this can be done will be improved as more sensitive measures of executive function, appropriate for the whole preschool age range, are developed. Developing such tasks remains an urgent goal for early executive function research (see Best & Miller, 2010 and Hughes, 2011 for further discussion of this issue).

The present data further contribute to our understanding of the suppression and reactivation of to-be-ignored information on developmental switching tasks. Interestingly, the current study found no evidence that children – even 2.5-year-olds – have any difficulty reactivating previously ignored information. There are two possible explanations for this observation, which are not mutually exclusive, but which remain to be disentangled. The first explanation is that difficulties reactivating information may only occur when children have to ignore and then reactivate specific *values* of a dimension (e.g. "blue"), not the dimension itself (e.g. "color"). Therefore, difficulties of this nature may be more likely to occur on CF tasks with a particularly small set size (e.g., where children sort two colors and two shapes) compared to CF tasks with a larger set size, as in the current study, possibly because the more frequently that specific distracting information appears, the more it will be the target of active suppression. The second explanation is that difficulties reactivating previously ignored information may only occur in the presence of response conflict. In the current study, children never have to resolve response conflict; the absence of conflict during the pre-switch phase means that there is little need for children to actively suppress their attention to the non-relevant information. This is consistent with previous findings that errors due to difficulties reactivating previously ignored information are reduced in older preschoolers when response conflict is removed during the pre-switch phase (Müller *et al.,* 2006). The present results suggest that this may also be the case for 2.5-year-olds.

One striking result was that when the to-be-ignored information was unrelated to the previous task, children's switching performance was very good – and indeed, no different to when they did not have to switch rules at all. This demonstrates that young preschoolers do not have problems with selective attention *per se*, and therefore already possess a necessary precursor ability for the development of advanced CF (Hanania & Smith, 2010). This is the first study to report that 2.5-year-olds can both selectively attend to a single dimension of a bivalent stimulus, and successfully switch their sorting behavior from one rule to another (providing that the need to suppress attention to previously relevant information is minimised). It is worth noting in the present study that the stimuli children sorted did not involve any response conflict. There are grounds for thinking that selective attention is particularly important when children must switch tasks in the presence of response conflict, and that under such circumstances, otherwise easily ignored information can disrupt behavior (e.g., Brooks *et al.,* 2003). However, the present data demonstrate that when response conflict is absent, even young preschoolers are able to switch from sorting by one rule to sorting by another.

The key finding from the present study is that children made more distraction errors when the to-be-ignored information was relevant during the pre-switch phase. However, there is an interesting comparison to be drawn between the present findings and those of the only other study we are aware of to look at distraction errors in preschoolers. Chevalier and Blaye (2008) reported that children *did* make distraction errors when the to-be-ignored information was not relevant during the pre-switch phase (on a task where children switched between different colors, rather than between color and shape). To reconcile this apparent difference, we suggest that a distinction should be drawn between *inter*-dimensional switching and *intra-*

dimensional switching. In Chevalier and Blaye's study, children made an *intra*-dimensional switch; that is, they sorted by color in both the pre-switch phase and post-switch phase, and switched between sorting pictures by different color values (yellow to blue). The to-be-ignored information was a specific color *value* that stayed constant throughout the task (green). Therefore the to-be-ignored information was relevant to the rule from the pre-switch phase (i.e. color). In the present study, children made an *inter*-dimensional switch; that is, they sorted by one dimension in the pre-switch phase and a different dimension in the post-switch phase. Crucially, distraction errors only arose when the to-be-ignored information was relevant to the rule from the pre-switch phase. Together, these results suggest that distraction errors will occur in the presence of information consistent with a previously relevant dimension, and will occur less in the presence of information not consistent with a previously relevant dimension. Specifically, children will make distraction errors if to-be-ignored information contains *any* perceptual information related to the previously relevant rule.

This study offers new insights into the causes of distraction errors, to complement the strong focus of previous research on perseverative errors. An important question for future work will be to examine further the distinct processes that underpin distraction errors and perseverative errors on cognitive flexibility tasks. While the aim of the present study was not to *compare* distraction errors and perseverative errors, but to examine *why* children make distraction errors, the question of how these errors differ and how they can be defined remains an important question to be resolved (see Carroll, Blakey & FitzGibbon, in press). Perseverative and distraction errors could be distinguished based on the consistency with which children err on a task. For example, preservative errors are typically defined as systematically repeatedly repeating a rule that is no longer relevant (e.g., Chevalier & Blaye, 2008) whereas distraction errors reflect sporadic, intermittent errors. However, it is also important to examine whether different underlying processes distinguish these two errors.

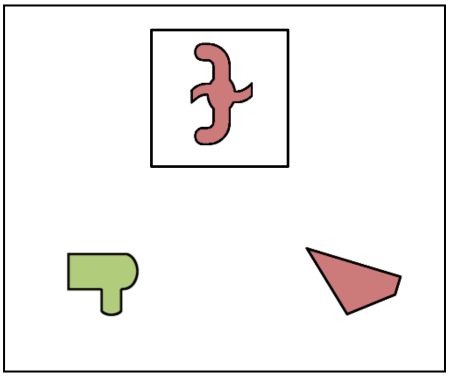
Perseverative errors may involve actively but incorrectly maintaining a no-longer relevant rule; in contrast, distraction errors may involve children maintaining the correct rule, but temporarily failing to maintain this rule when presented with distracting information related to a previous goal. Indeed, in the present study after a change in rule, *all* children in the present study sorted more trials correctly than incorrectly, suggesting they adopted an appropriate new rule to guide their post-switch behavior. Addressing these questions definitively is likely to require new experimental paradigms to study children's performance on tasks where the two kinds of error might co-occur, since existing paradigms are poorly suited for this purpose. To consider a hypothetical example: in the case of a child who perseverated for 6 out of 8 post-switch trials on the DCCS task (where children resolve response conflict), it would be difficult to determine whether the two correct trials reflected a distraction error, where the child momentarily failed to apply the rule they were (incorrectly but systematically) sorting by, or whether they reflected a brief instance of successfully applying the correct rule. Teasing apart perseverative errors and distraction errors is likely to be an ongoing challenge – but doing so will be essential for gaining a full understanding of how cognitive flexibility develops.

The present study offers valuable insights into the nature of distraction errors in CF, and provides the first evidence to explain how these errors arise. This approach provides a new and essential complement to the substantial body of evidence looking at perseverative errors, and begins to shed light on the task demands that remain in CF even after the need to avoid perseveration is removed. It is now clear that young preschoolers' switching performance is not inevitably disrupted by any kind of distracting information. Instead, the distraction errors they make are goal-related in nature: they arise from continued attention towards the dimension children previously sorted by. Furthermore, this influence persists even when it is not possible to continue to match by the previously relevant rule. The study suggests that the ability to maintain the relevant task rule in the face of distracting information may be supported by children's developing inhibitory control. Together, these results suggest not only that key developments occur between the ages of 2.5 and 3 years, but also that systematically maintaining goal-directed behavior in the face of distractions is a fundamental milestone in the development of flexible cognition.

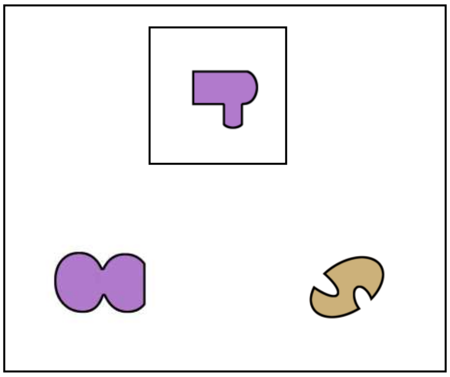
Figure 1: The four different conditions on the SwIFT

Baseline non-switching SwIFT:

Pre-switch: "Touch the one that's the same *color*"

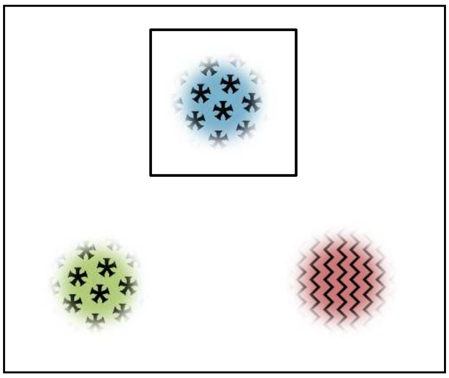


Post-switch: "Touch the one that's the same *color*"

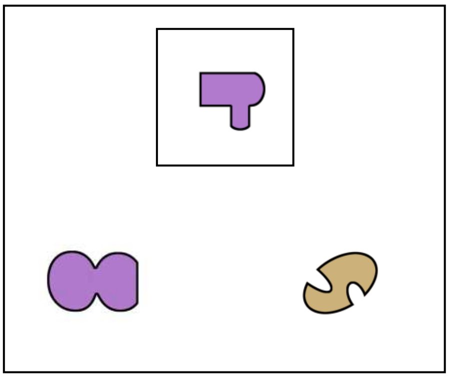


Goal-Unrelated SwIFT:

Pre-switch: "Touch the one that's the same *pattern*"

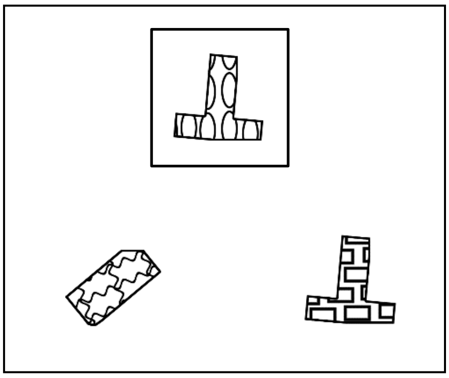


Post-switch: "Touch the one that's the same *color*"

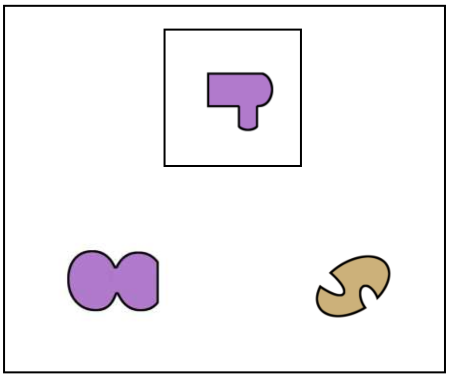


Goal-Related SwIFT:

Pre-switch: "Touch the one that's the same *shape*"

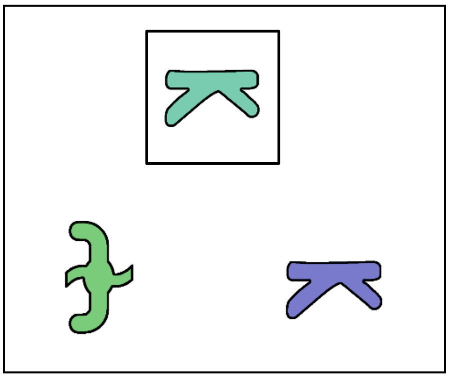


Post-switch: "Touch the one that's the same *color*"



Goal-Related Reactivation SwIFT:

Pre-switch: "Touch the one that's the same *shape*"



Post-switch: "Touch the one that's the same *color*"

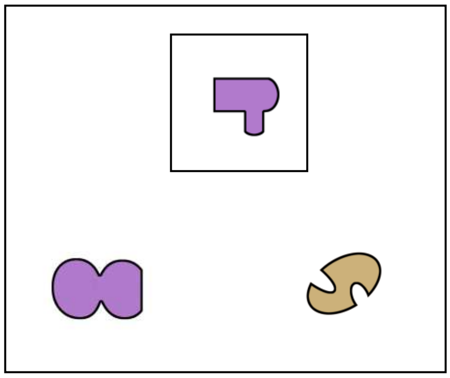
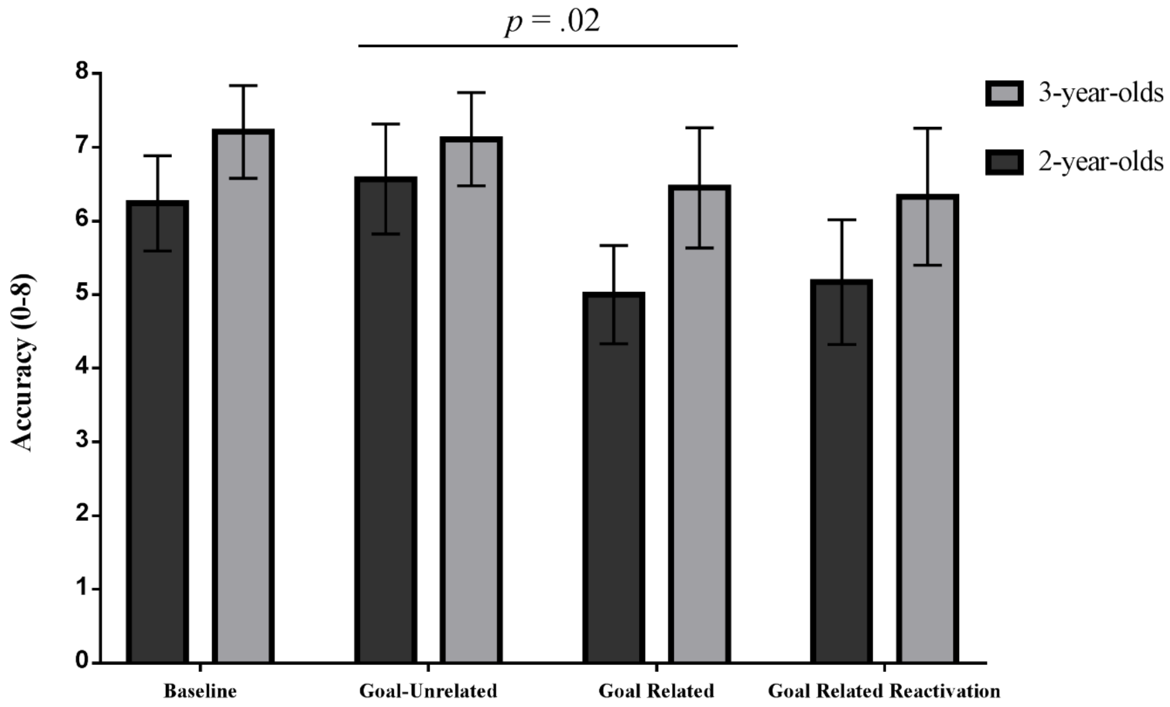


Figure 2. Mean post-switch accuracy (0-8) by condition and age including 95% confidence intervals.



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